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# SYSTEM AND METHOD FOR FACILITATING DIAGNOSIS OF CARDIAC RHYTHM DISORDERS WITH THE AID OF A DIGITAL COMPUTER

## CROSS-REFERENCE TO RELATED APPLICATION

This non-provisional patent application is a continuation-in-part of U.S. patent application Ser. No. 14/997,416, filed Jan. 15, 2016, now U.S. Pat. No. 9,345,414, which is a continuation-in-part of U.S. patent application Ser. No. 14/614, 265, filed Feb. 4, 2015, pending; which is a continuation-in-part of U.S. patent application Ser. No. 14/488,230, filed Sep. 16, 2014, pending; which is a continuation-in-part of U.S. patent application Ser. No. 14/080,725, filed Nov. 14, 2013, pending, and further claims priority under 35 U.S.C. §119(e) to U.S. Provisional Patent application, Ser. No. 62/132,497, filed Mar. 12, 2015, the disclosures of which are incorporated by reference.

## FIELD

This application relates in general to electrocardiographic monitoring and, in particular, to a method for facilitating diagnosis of cardiac rhythm disorders with the aid of a digital computer.

## BACKGROUND

An electrocardiogram (ECG) allows physicians to diagnose cardiac function by visually tracing the cutaneous electrical signals (action potentials) that are generated by the propagation of the transmembrane ionic currents that trigger the depolarization of cardiac fibers. An ECG trace contains alphabetically-labeled waveform deflections that represent distinct features within the cyclic cardiac activation sequence. The P-wave represents atrial depolarization, which causes atrial contraction. The QRS-complex represents ventricular depolarization. The T-wave represents ventricular repolarization.

The R-wave is often used as an abbreviation for the QRS-complex. An R-R interval spans the period between successive R-waves and, in a normal heart, is 600 milliseconds (ms) to one second long, which respectively correspond to 100 to 60 beats per minute (bpm). The R-wave is the largest waveform generated during normal conduction and represents the cardiac electrical stimuli passing through the ventricular walls. R-R intervals provide information that allows a physician to understand at a glance the context of cardiac rhythms both before and after a suspected rhythm abnormality and can be of confirmational and collaborative value in cardiac arrhythmia diagnosis and treatment.

Conventionally, the potential of R-R interval context has not been fully realized, partly due to the difficulty of presentation in a concise and effective manner to physicians. For instance, routine ECGs are typically displayed at an effective paper speed of 25 millimeters (mm) per second. A lower speed is not recommended because ECG graph resolution degrades at lower speeds and diagnostically-relevant features may be lost. Conversely, a half-hour ECG recording, progressing at 25 mm/s, results in 45 meters of ECG waveforms that, in printed form, is cumbersome and, in electronic display form, will require significant back and forth toggling between pages of waveforms, as well as presenting voluminous data transfer and data storage concerns. As a result, ECGs are less

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than ideal tools for diagnosing cardiac arrhythmia patterns that only become apparent over an extended time frame, such as 30 minutes or longer.

R-R intervals have also been visualized in Poincaré plots, which graph RR(n) on the x-axis and RR(n+1) on the y-axis. However, a Poincaré plot fails to preserve the correlation between an R-R interval and the R-R interval's time of occurrence and the linearity of time and associated contextual information, before and after a specific cardiac rhythm, are lost. In addition, significant changes in heart rate, particularly spikes in heart rate, such as due to sinus rhythm transitions to atrial flutter or atrial fibrillation, may be masked or distorted in a Poincaré plot if the change occurs over non-successive heartbeats, rather than over two adjacent heartbeats, which undermines reliance on Poincaré plots as dependable cardiac arrhythmia diagnostic tools. Further, Poincare plots cannot provide context and immediate temporal reference to the actual ECG, regardless of paper speed. Events both prior to and after a specific ECG rhythm can provide key clinical information disclosed in the R-R interval plot that may change patient management above and beyond the specific rhythm being diagnosed.

Therefore, a need remains for presenting R-R interval data to physicians to reveal temporally-related patterns as an aid to rhythm abnormality diagnosis.

## SUMMARY

R-R interval data is presented to physicians in a format that includes views of relevant near field and far field ECG data, which together provide contextual information that improves diagnostic accuracy. The near field (or short duration) ECG data view provides a "pinpoint" classical view of an ECG at traditional recording speed in a manner that is known to and widely embraced by physicians. The near field ECG data is coupled to a far field (or medium duration) ECG data view that provides an "intermediate" lower resolution, pre- and post-event contextual view.

Both near field and far field ECG data views are temporally keyed to an extended duration R-R interval data view. In one embodiment, the R-R interval data view is scaled non-linearly to maximize the visual differentiation for frequently-occurring heart rate ranges, such that a single glance allows the physician to make a diagnosis. All three views are presented simultaneously, thereby allowing an interpreting physician to diagnose rhythm and the pre- and post-contextual events leading up to a cardiac rhythm of interest.

The durations of the classical "pinpoint" view, the pre- and post-event "intermediate" view, and the R-R interval plot are flexible and adjustable. In one embodiment, a temporal point of reference is identified in the R-R interval plot and the ECG data that is temporally associated with the point of reference is displayed in the near field and far field ECG data views. In a further embodiment, diagnostically relevant cardiac events can be identified as the temporal point of reference. For clarity, the temporal point of reference will generally be placed in the center of the R-R interval data to allow pre- and post-event heart rhythm and ECG waveform data to present in the correct context. Thus, the pinpoint "snapshot" and intermediate views of ECG data with the extended term R-R interval data allow a physician to comparatively view heart rate context and patterns of behavior prior to and after a clinically meaningful arrhythmia, patient concern or other indicia, thereby enhancing diagnostic specificity of cardiac rhythm disorders and providing physiological context to improve diagnostic ability.